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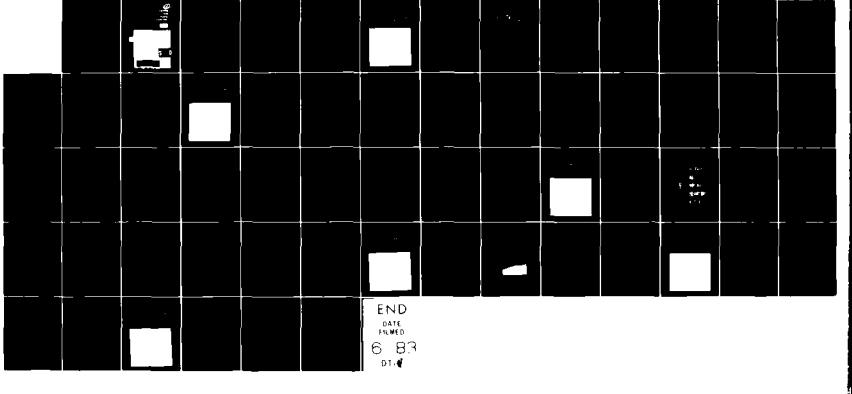

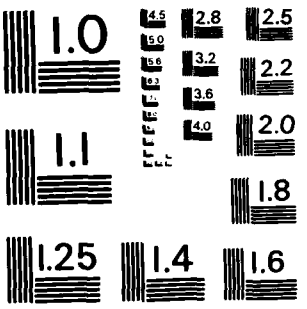

FOREWORD

The year 1982 marked the twentieth anniversary of the Center for Naval Analyses and the fortieth of its Operations Evaluation Group, around which CNA was formed. A book-length history of OEG, relating the Group's contributions to this nation's Naval strength, will be published in 1983. These contributions, now as before, depend mainly on OEG's practice of sending analysts into the "field," at Naval commands around the world, to analyze and assess tactics, operations, and systems. Section I of this report gives special attention to OEG's field program and the activities of field representatives.

The field program also figures prominently in the summaries of CNA's research results for 1982 which are given in section II. Some of the projects summarized there also represent the new types of research that have been undertaken by the Naval Studies Group, which was formed as fiscal year 1982 began. With the creation of NSG, CNA reoriented its program of studies for Navy planning offices in Washington. There is less emphasis on finding ways to apply such standard analytic techniques as cost-effectiveness analysis, and more emphasis on broad, basic issues that do not always lend themselves to the cut-and-dried application of standard techniques. New areas of concern include the adaptation of new technology by Naval forces, improvement of Navy planning methods, and development of a tighter link between U.S. naval strategy and our allies' naval capabilities. Section III describes the organization of NSG and the rest of CNA, in some detail.

Readers with a particular interest in Marine Corps matters will find in sections II and III summaries of selected research for the Marine Corps and a description of the Marine Corps Operations Analysis Group, which conducts the research. With a relatively small staff, MCOAG covered a lot of analytical ground in 1982, completing major studies in these subjects: the adequacy of fire support for amphibious operations, automation of command and control systems, modernization of the Marine Corps' entire fleet of trucks and trailers, validity of a test of new

anti-armor vehicles, and effectiveness of enlistment bonuses. MCOAG also continued to take a leading role in the assessment and improvement of military aptitude tests – for the benefit of all four military services.

The quality of the analysis done by CNA's three research groups depends foremost on the quality of the research staff. Continual improvement of the staff's quality has been a major goal of the University of Rochester, since the University assumed responsibility for the management of CNA in 1967. In 1982, four University officials, who are also members of CNA's Board of Overseers, reviewed the Center's procedures for recruiting analysts and rating their performance. The review found that these procedures are thorough and effective. For instance, CNA has been successful in recruiting graduate students with strong credentials from top-ranked universities. And CNA's written performance evaluations convey explicit information about analysts' strengths and point out areas for improvement. The qualifications of CNA's research staff are highlighted in section IV.

To give greater impetus to CNA's new lines of research, a number of highly-qualified, experienced analysts were hired in 1982, to head new programs and projects. Funding, discussed in section V, increased enough in 1982 to allow this shift toward a more senior staff, while holding steady the total number of research staff members.

Finally, in 1982, the Board of Overseers ~~whose~~ membership is listed in section VI – lost the services of Admiral C. Donald Griffin, USN (Ret.), who retired after fourteen years on the Board. On his retirement, Admiral Griffin was elected to honorary membership.

W. Allen Wallis, Chairman of the Board since its formation in 1967, had to relinquish his post on becoming Under Secretary of State for Economic Affairs. Mr. Wallis had been instrumental in framing and preserving the special relationship between the Navy Department and CNA. He raised the standards of quality for CNA's research, and guided the Center toward those standards.

To these former colleagues, our thanks and best wishes, on behalf of the Center for Naval Analyses and the University of Rochester.

David Kassing

DAVID KASSING
President

Robert L Sproull

ROBERT L. SPROULL
Chairman of the Board

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ANALYSIS AND NAVAL OPERATIONS

As a means of providing the widely dispersed operating forces of the Navy with analytical support, CNA's Operations Evaluation Group (OEG) assigns 36 analysts – more than half of its scientific staff – to Naval commands around the world, for tours of one to three years. The map and table on page 2 show where OEG's field analysts serve.

These analysts have a variety of tasks: They help develop war plans involving alternative force dispositions; take part in the planning and analysis of exercises to find out what present forces can do; assist in developing and evaluating new tactics to make the forces more effective; and, at test and evaluation facilities, help in the operational testing and evaluation of major combat and combat support systems. In sum, field representatives help to assess current readiness and effectiveness, and they look for ways to improve both.

The data collected and analyses done in the field, in addition to their value to Naval commands, are important to the CNA-Washington research program. They form the basis for realistic estimates of how well present and future weapon systems may be expected to perform in combat. The returning field representative is often able to follow up such questions at CNA-Washington, where he may work with other specialists in a specific warfare area or with an interdisciplinary study team examining a range of possible force structures.

The influence of the field program on the CNA-Washington program – and the interactions between the two – is reflected in the summaries of CNA's research results for 1982, in section II of this report. (See especially the summaries under the heading "Current Forces and Operations.")

The rest of this section focuses on the activities of field representatives and their direct contributions to the Navy. First, a sketch of the development of the field program, from the early days of OEG to the present, illustrates the variety of problems in naval warfare that analysts in the field have dealt with – and deal with today. Then, the activities of field representatives are discussed, with special attention to tactical development and exercise analysis.

* * *

In the spring of 1942, with OEG – then called the Antisubmarine Warfare Operations Research Group (ASWORG) – only a few weeks

OEG IN THE FIELD

ASSIGNMENTS IN 1982

BRUNSWICK
Commander, Patrol Wings, Atlantic

CHARLESTON
Commander, Cruiser-Destroyer Group Two

CHINA LAKE
Air Test and Evaluation Squadron Five

GAETA
Commander, Sixth Fleet

HAWAII
Commander in Chief, Pacific Fleet
Commander, Third Fleet
Commander, Submarine Force, Pacific

KAMISEYA
Commander, Patrol and Reconnaissance Force, Seventh Fleet

LEMOORE
Commander, Light Attack Wing, Pacific

LONDON
Commander in Chief, U.S. Naval Forces, Europe

MAYPORT
Commander, Cruiser Destroyer Group Twelve
Commander, Carrier Group Six

MOFFETT FIELD
Commander, Patrol Wings, Pacific

NAPLES
Commander, Battle Force, Sixth Fleet
Commander, Submarine Force, Sixth Fleet
Commander, Maritime Surveillance and Reconnaissance Force, Sixth Fleet
Commander, Area Antisubmarine Warfare Force, Sixth Fleet

NEW LONDON
Commander, Submarine Development Squadron Twelve

NEWPORT
President, Naval War College

NORFOLK
Commander in Chief, Atlantic/U.S. Atlantic Fleet
Commander, Naval Air Force, Atlantic
Commander, Second Fleet
Commander, Tactical Wings, Atlantic
Commander, Surface Warfare Development Group
Tactical Training Group, Atlantic
Commander, Operational Test & Evaluation Force

PATUXENT RIVER
Air Test and Evaluation Squadron One

PT. MUGU
Air Test and Evaluation Squadron Four

SAN DIEGO
Commander, Naval Surface Force, Pacific
Commander, Antisubmarine Warfare Wing, Pacific
Commander, Fighter Airborne Early Warning Wing, Pacific
Tactical Training Group, Pacific
Deputy Commander, Operational Test & Evaluation Force, Pacific

SUBIC BAY
Commander, Carrier Striking Force, Seventh Fleet

WHIDBEY ISLAND
Commander, Medium Attack Tactical Electronic Warfare Wing, Pacific

YOKOSUKA
Commander, Seventh Fleet

old, the Navy decided that operations research scientists should be where the operations were. In this way, the group would be exposed, first hand, to actual operations, would have access to reliable and abundant operational data, and could produce analyses that would hold up under the rigors of combat. Over the ensuing months of the war, ASWORG's field program expanded rapidly as more and more commands became convinced of the usefulness of having ASWORG scientists assigned to them.

The Navy reaped significant benefits from these assignments, as the analysts helped front-line forces deal with a variety of combat problems. Among the many forms of this support during the war was the development of more effective plans for searching for the elusive U-boat and for screening convoys; determination of the preferred size of convoys and of the effect of ship speed on convoy safety; and the design of countermeasures to the acoustic torpedo, the radar search receiver, and the snorkel-equipped submarine.

Although the field program became less active with the end of the war – with field assignments confined to the Operational Development Force and the Key West Evaluation Detachment – the lull was short-lived. The early 1950s witnessed the complete rebound of the program, spurred in part by the outbreak of hostilities in Korea. Several analysts were assigned immediately to the staffs of the Commander-in-Chief of the Pacific Fleet and the Commander of Naval Forces in the Far East. These analysts helped to solve tactical problems and suggested ways to improve operations on the scene. Some of the subjects examined during the war were naval gunfire support of ground forces, scheduling and effectiveness of close air support, interdiction of land transportation, selection of weapons for tactical air attacks, and blockade of the enemy's coastline.

Quite apart from what was going on in the war, requests for analytical assistance began to reach OEG from increasing numbers of other commands, including the Commander-in-Chief of the Atlantic Fleet; the Second, Sixth, and Seventh Fleets; the Commander of ASW Forces in the Atlantic; and Air Test and Evaluation Squadrons One, Three, and Five.

For the remainder of the 1950s and into the early 1960s, OEG continued to expand its field program. One of the more significant

studies done in the field at the time concerned defense of the fleet against planes and submarines. The analysis concluded that enemy attempts to detect and identify carrier forces could be thwarted by widely dispersing friendly forces, using noncombatant shipping to help confuse enemy reconnaissance efforts, having escort ships patrol far in advance of the main force, and vigorously employing electronic countermeasures, decoys, and tactical deception. After these proposals were tested in naval exercises, specific measures were adopted by the fleets.

Another study investigated the reliability and effectiveness of the Navy's new shipborne surface-to-air missile systems. Related to this, the OEG representative assigned to the Commander-in-Chief of the Atlantic Fleet prepared a study on how best to station these missile-firing ships. This work led to revised fleet doctrine for ship stationing. An investigation was also made of a missile ship's ability to open fire after a period of electronic silence. The analysts assigned to the Operational Test and Evaluation Force recommended a series of exercises designed to test this ability under rigorous conditions.

From 1965 on, with the fighting in Southeast Asia heating up, OEG began to commit considerable resources to the war. As in the Korean War fourteen years before, the group assigned a team of analysts to the Commander-in-Chief of the Pacific Fleet in Hawaii. Other OEG representatives were sent to the Seventh Fleet in the Western Pacific and to Task Force 77, operating off the coast of North Vietnam.

A significant portion of the analytical effort expended by these analysts was centered on learning more about the causes of loss or damage of aircraft in the various air operations in which the Navy took part. The many studies of attrition led to changes in tactics that contributed to marked reductions in aircraft losses. Other analyses evaluated the performance of new aircraft and weapon systems. Still others examined the results of dogfights between U.S. Navy and enemy planes, and of air attacks against transportion routes on the ground. Finally, some effort was devoted to gauging the effectiveness and efficiency of operations designed to hamper the enemy's use of the coastline and rivers for moving arms, supplies, and people.

Although OEG's field program has been influenced by a number of external events, it received what was perhaps its greatest impetus in

late 1970, when the Navy asked OEG to manage its Tactical Analysis Group (TAG) program. The purpose of the TAG program was to help fleet commanders plan, conduct, and later reconstruct and analyze antisubmarine exercises. By adding the TAG analysts to its field program, OEG effectively doubled its commitment of analysts to billets outside Washington. Among the newly supported commands were the Submarine Force in the Pacific, Fleet Air Wings in the Atlantic, Destroyer Development Group Two, and Submarine Development Group Two.

The TAG analysts became involved in a wide range of topics. One analyst examined the U.S. submarine in defending convoys and task forces against enemy submarines, conducting surveillance, and mining. Another analyst investigated the effectiveness of various types of antisubmarine patrol planes, and ways to better integrate the operations of a mix of such planes from a single carrier deck. Other work included development of a mathematical model to aid evaluations of alternative force mixes in detecting, attacking, and killing enemy submarines; examination of methods of surveillance of submarines; and analysis of the relative effectiveness of various antisubmarine search plans and configurations, before testing at sea.

In 1973, the TAG program was affected by establishment of the Navy-wide Tactical Development and Evaluation (TacD&E) program. The Navy decided that the TAG analysts would provide TacD&E projects with their main analytical support. The result was diversification of the TAG program to cover a wide range of warfare areas, not antisubmarine warfare alone. Typical subjects of investigation have been the operation of a task group in the face of a highly diversified threat on and beneath the ocean and in the air, and the planning of force deployments and configurations that deceive and confuse an enemy.

While the activities of analysts at TAG commands became more diverse, analysts at the non-TAG commands continued to conduct short-term studies of problems the commands needed to solve immediately. They also helped to plan and evaluate fleet operations and measure the performance of forces and new equipment. An OEG analyst with the Commander-in-Chief of the Atlantic Fleet, for example, helped devise a fixed-perimeter defense for attack carrier strike forces, to provide protection against submarines. Another field

representative, aboard the flagship of the Seventh Fleet, investigated the effectiveness of airborne electronic intelligence. At the Operational Test and Evaluation Force, an analyst developed tests and measures of effectiveness for evaluating the performance of a new torpedo, surface search radar, air-to-air missile, and airborne direction-finding system.

* * *

The field program has thus come to support the far-flung and varied Naval commands that it does today. In giving this support, field representatives work under the same conditions as the staffs they are assisting, and many spend considerable time at sea.

The final decision regarding the problems to be analyzed rests with the commander. At some commands, the analysts' work fits into well defined analytic programs; at others, the analysts have a freer hand in selecting the programs of study. Much depends on the interaction of the individual analyst with the commander and his staff.

Currently, more than half the field representatives are assigned to specific projects in support of the Tactical Development and Evaluation program. As its name implies, the purpose of TacD&E is to develop and evaluate tactics, so that the ships, planes, sensors, weapon systems, and all the other equipment contributing to the Navy's effectiveness may be used to best advantage.

Tactics may be evaluated both ashore and at sea; each approach presents both advantages and disadvantages. The virtue of evaluating tactics ashore is that the analyst can use analytical models to investigate the effects of changing any of the parameters. Further, many variables — based on past exercises, operations, and analyses — may be introduced into the models. The models can then be run as often as desired, enabling the analysts to try various combinations of variables. In this way, the analyst may evaluate a tactic under a variety of conditions that challenge its usefulness. A drawback, however, is the possibility of inadvertently omitting from the model some factor whose absence might distort the outcome.

The virtue of evaluating tactics at sea, on the other hand, is that tests can be somewhat realistic. In particular, it helps enormously to observe ships, planes, and submarines opposing each other in the often

unpredictable environment of the real world. Certainly, such an environment enhances believability. But a test at sea, unlike models that may be run over and over, represents only one set of conditions, making the results less general. The solution to achieving both operational realism and statistical confidence, then, is to evaluate newly developed tactics by means of both sea tests and analytical models.

Sometimes, new tactics are tested at sea during naval exercises, which serve other purposes as well – the improvement of fleet readiness and assessment of newly deployed systems – and are therefore a major focus of field activity.

Some exercises call for the use of only one unit, such as a ship or submarine, and are designed to provide crews with refresher training or with an opportunity to test a new system. Other exercises involve several units – as many as five to ten ships plus planes – with the object of practicing a single mission, such as antisubmarine or electronic warfare or the use of surface-to-air missiles. Some thirty of these exercises are run every year. Then there are fleet-wide exercises, involving a variety of forces with different missions, and sometimes including the forces of allied countries. About a dozen of these exercises are run every year, lasting as long as ten days and involving up to fifty ships plus an assortment of planes.

Exercises are subject to unavoidable artificialities that distort operations enough to make an analyst wary of projecting from the results of an exercise to combat situations. For instance, the fact that real ordnance is not used in an exercise means that the accuracy of targeting and weapon delivery cannot be evaluated, nor can damage be assessed. A concern for safety keeps opposing units, such as submarines, farther apart than would be expected in real battle, to avoid collisions. Also, because our own forces play the enemy, the capabilities of enemy ships, planes, submarines, weapon systems, and sensors – and the tactics that guide their use – cannot be simulated closely. Still other artificialities arise from the scenario for an exercise, including a limited area of ocean in which the battle is to unfold, a specified choice of tactics, and a combat problem that is simpler than any that are likely to be encountered.

Despite these imperfections and many others, tests at sea provide the only means of learning how forces might perform in combat. It is

therefore important to learn as much as possible from exercises, through analysis. This is where the OEG field representative enters the picture.

The OEG analyst plays many roles, before, during, and after an exercise. Usually, the analyst's first responsibility, once an exercise has been scheduled, is to work with the commander and operations officer to specify the objectives of his analysis. These objectives depend on the types of missions to be practiced (for example, protection of the battle group against air attacks), the types and numbers of units taking part, and the scenario that guides the mock battle. For antisubmarine warfare, for example, the analytical objective may be to determine the ability of the ships and planes of a battle group to detect and track enemy submarines in waters in which sonar detection is difficult. In electronic warfare, the objective may be to evaluate the ability of units in the battle group to maintain total electronic silence during vulnerable periods.

Planning also requires the analyst to identify the types of data that exercise participants should collect, and to arrange for analytical assistance, as needed. Help may come from OEG field representatives assigned to other commands and from analysts in Washington. As many as ten analysts have contributed to the study of a fleet-wide exercise.

The next step is data collection. Some data tell when opposing forces were detected and which were fired on, where the opposing forces were, and when. Other data record the performance of such sensors as radars and sonars. Still other data come in the form of judgments by invididuals – pilots, for example – who have participated in the exercise. There are also accounts by commanders, which usually point to the more significant events of the exercise. Finally, the OEG analysts are usually aboard key ships or aircraft as the exercise unfolds, observing operations and recording data. The end project is reams of information – for a major exercise, several hundred pounds of paper – to be sifted through when the exercise is reconstructed.

"Gross" reconstruction yields time-position plots of the tracks of participants, obtained from position logs and navigational satellite data. These provide the backdrop for developing a systematic view of major events – the time and place of attacks, changes in the disposition of

forces, and execution of deception plans, for example. From this gross reconstruction, the analyst can specify periods of the exercise that merit "finer-grained" reconstruction, to answer questions about the details of such complex, fast-moving events as engagements between fighter aircraft and incoming bombers.

Toward the end of reconstruction, the data that seem most useful are organized into summary tables and graphs. In this way, relations among the data are made apparent and can be readily examined. Tables of data on antiair warfare, for instance, may show the time an air raid took place, the composition of the raid, the number of enemy planes detected, the percentage effectively engaged, and the units that engaged them.

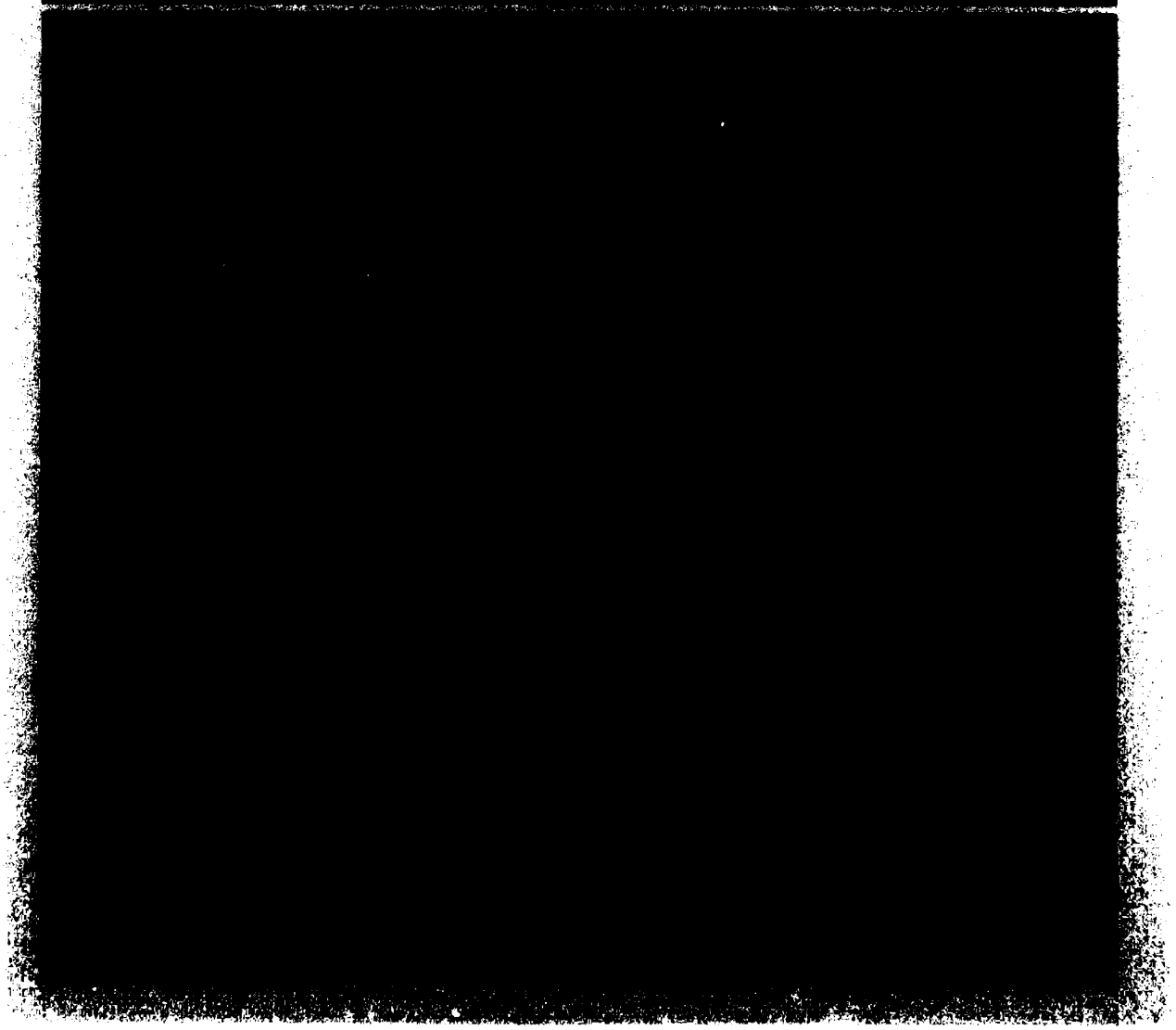
The analyst is thus able to assemble an accurate picture of events in the exercise, assess the performance of participants quantitatively, and answer such questions bearing on the analytical objective of the exercise as these: "How long can a U.S. carrier battle group withstand Soviet bomber attacks?" and "Will the Soviet diesel submarine be able to penetrate the carrier's escort screen?" In addition, the analyst might pinpoint deficiencies in established or newly developed tactics, prompting their revision or rejection. He reports the conclusions drawn from the analysis – along with a narrative description of the exercise and, possibly, recommendations with supporting evidence – to the participants in the exercise and to other interested commands in the Naval community.

However, a single exercise is usually an inadequate basis for conclusions about the Navy's ability to perform a tactic or conduct a mission. Sometimes, then, several exercises of similar type are conducted. For example, in the course of two years, the Sixth Fleet held several exercises in the Mediterranean Sea to test the use of the Harpoon antiship cruise missile. OEG field representatives, backed by analysts in Washington, observed the many simulated firings of Harpoon, then reconstructed and analyzed the events. At the conclusion of the series of exercises, the analysts were able to point out problems in the use of Harpoon and propose improvements. These included ways to set priorities among alternative targets, to coordinate the launching of missiles by several Harpoon-firing ships, and to determine the position of an enemy ship that is over the radar horizon. The summaries of research in section II of this report, under

"Fleet Exercises and Fleet Effectiveness," illustrate further the contributions of exercise analysis.

Thus the analysis of exercises is an essential part of the field representatives' efforts to help the Navy assess and improve its tactics, the readiness of its forces, and the performance of its equipment. The effectiveness of these efforts flows from adherence to the principle on which OEG's field program was founded, four decades ago: Operations analysts must be where the operations are, to have direct and unimpeded access to vital data, and to guarantee the realism and relevance of their analyses. Indeed, the field program is unarguably central to OEG's long-held charter of helping the Navy get the most out of the forces it has now and will have soon.

1982
RESULTS



The examples in this section represent only a portion of CNA's research during FY 1982. Classified details have, of course, been excluded. Nevertheless, these brief descriptions give something of the flavor of CNA research in the past year. The research outlined here is reported in detail in CNA publications; classified publications are available to qualified recipients.

Projects on the same general subject have been grouped under one heading; altogether, some 30 projects are represented. These are the subjects covered:

Current Forces and Operations
- Antiair Warfare in the Missile Age
- Antisubmarine Aircraft Operations – Assessment and Improvement
- Fleet Exercises and Fleet Effectiveness

Future Forces and Support Systems
- Fire Support for Amphibious Operations
- New Missiles for Fleet Air Defense
- Logistic Support for ASW Helicopters
- How Much Automation of Marine Corps Command and Control?
- A New Generation of Vehicles for the Marine Corps

Manpower and Management
- Strengthening the Navy's Enlisted Personnel Force
- Better Tools for Navy Decision-Makers

Non-Defense Research

CURRENT FORCES AND OPERATIONS

Antiair Warfare in the Missile Age

Aircraft carrier battle groups face the major threat of Soviet bombers armed with long-range cruise missiles. CNA analysts, with the fleet and in Washington, have been helping the Navy evaluate and refine the approach its air defense forces would use in dealing with the threat.

One aspect of CNA's work involves the positioning of F-14 air defense fighters at combat air patrol (CAP) stations. The CAP aircraft rely on

tanker aircraft for on-station refueling, thus increasing the number of fighters available to defend the battle group. The ability of the tanker aircraft to keep the fighters refueled has been evaluated by CNA analysts. Their computations have taken into account the amount of fuel needed by the fighters, the amount of fuel that can be carried by the tankers, the time it takes the carrier to fuel and relaunch the tankers, the position of the fighters in relation to the carrier, and the time and duration of an attack.

Their results have shown that with the tankers now available it would be difficult to keep on station as many fighters as desired. Possible solutions are to buy more fuel pods for converting attack aircraft to temporary tankers, purchase a larger tanker, or purchase a new fighter engine that may reduce fuel usage by a third, reducing proportionally the need for tanker support.

Another way to improve the effectiveness of the Navy's fighter aircraft is through countertargeting. This is a relatively new concept in naval warfare. It refers to measures to deny Soviet cruise missile bombers a clear shot at the carrier from long range, thus giving fighter aircraft more time to intercept the bombers.

The CNA-initiated countertargeting project has grown to involve a number of Navy laboratories and commands. The project has evaluated the effectiveness of countertargeting equipment, through operations analysis, laboratory simulation, and at-sea tests. In addition to helping design and conduct the tests, CNA analysts have written detailed reports and presented the results widely throughout the Navy.

The air defenses of a battle group include, in addition to fighter aircraft, antiair warfare (AAW) escort ships, which operate in a screen around the aricraft carrier. As the main job of the fighters is to shoot down enemy bombers early in the attack, the main job of the AAW escorts is to shoot down any missiles that are fired.

Until recently, the defense coverage afforded by individual ships would be expressed in terms of the maximum intercept range of their surface-to-air missiles. The available SAM ships would then be placed where their intercept envelopes could cover the potential routes for a missile attack. However, this method fails to reflect the dynamics of missile-on-missile engagements, in which time is a critical factor. CNA

analysts have therefore developed new procedures for stationing SAM ships so that they will have adequate time for successful engagements.

To derive stationing guidelines for ships that are equipped with the new SM-2(ER) guided missile system, CNA analysts have developed a computer model of the system. The model takes account of the system's physical parameters, the number and spacing of incoming missiles, and the position of the SAM ship in relation to the threat and the unit it is defending.

Antisubmarine Aircraft Operations – Assessment and Improvement

The P-3 is the U.S. Navy's land-based maritime patrol aircraft. With a variety of sensors designed to find, track, and attack submarines, the P-3 has been a mainstay of the Navy's antisubmarine warfare (ASW) force for many years. The present model of the P-3 has more capable ASW systems than its predecessors, and can also be used for anti-surface warfare and minelaying. CNA analysts have played an important role in the evolution of the P-3, particularly in the development of tactical guidelines for its new systems and assessment of the aircraft's performance in its various missions. During the past year, for example, CNA analysts have worked with the Navy to devise procedures for sowing minefields by the P-3. CNA has also helped to develop procedures for surface search by the P-3 and for employment of its antiship missile.

ASW continues to be the P-3's primary mission, and CNA analysts have provided fleet operators with improved tactical guidelines for using sonobuoys – small sonar units that a P-3 drops into the water and monitors. CNA has also assessed the role of the P-3 in the ASW defense of an aircraft carrier and its escorts.

The effectiveness of the P-3 and the Navy's other ASW aircraft depends critically on the ability of sonar to recognize enemy submarines by their characteristic sounds. To help the operations, the Navy has developed automatic detection and computer-assisted classification (AD/CAC) systems. The Navy asked CNA to analyze the criteria that operators and AD/CAC machines use in determining whether or not they have detected a submarine. In particular, the Navy wanted CNA to define these criteria, determine how effective they are, and suggest how they might be improved.

The study team reviewed training documents and interviewed operators to define the classification criteria now in use. The analysts also examined criteria used by AD/CAC machines. The team assessed the classification performance of antisubmarine aircraft crews against submarines, using data reported by every crew after each flight. Finally, to help the Navy decide which rules its operators and AD/CAC machines should use, under various conditions, the team compared alternative decision rules in terms of ability to distinguish the signatures of different submarines and ships.

Other CNA analysts have been concerned with ASW operations in specific areas of the world. Much attention has been given to the Indian Ocean, where ASW is made especially difficult by the effects of the ocean's thermal structure, high levels of shipping noise on acoustic sensors, and the distances that land-based ASW aircraft must transit. This hampers the Navy's constant search for submarines that may be near U.S. battle groups operating in the Arabian Sea. Data from operations there have yielded insights into the performance of Naval ASW systems in the region.

When units are sent to check the validity of a possible detection of a submarine, a report is written describing the encounter. Battle groups and supporting ASW aircraft also conduct periodic training exercises against U.S. submarines. The results and lessons drawn from these exercises are also reported.

To determine which types of ships, aircraft, and sensors make initial detections of submarines and which contribute to investigations of detections, CNA field representatives analyze the reports of contacts. They also assess the general validity of the detections and estimate the ranges of the valid ones. Their analyses of exercise reports have provided additional information about sonar conditions, detection ranges, and the effectiveness of various ASW units and sensors.

Fleet Exercises and Fleet Effectiveness

Exercises enable the fleet to train people, test systems, and develop tactics in the benign environment of mock combat. All attacks are simulated, and the losers survive to learn from their mistakes. For the lessons to be valid, however, exercise participants must have a complete and accurate account of what took place at sea. In addition, the

lessons must be set in context. Because of exercise-to-exercise variations in scope, scenario, and conduct, the results of any one exercise will rarely support firm conclusions about the fleet's effectiveness. Only by evaluating and comparing results from many different exercises can performance trends be discerned and widespread problems be identified.

In 1982, as before, CNA analysts helped to plan, monitor, reconstruct, and analyze the outcomes of individual exercises, and they made detailed studies of long series of exercises. Much of the work on individual exercises was performed by CNA field representatives, with help from their Washington-based colleagues. They analyzed all types of exercises, ranging from small, impromptu exercises-of-opportunity to large, freeplay battle group exercises.

An exercise-of-opportunity can take place any time a surface task force passes near a friendly submarine or another group of surface warships. This gives the task force commander a convenient means of practicing the tactics he would use against hostile submarines and ships. When analytical support is available for these activities, it is usually given by the CNA representative assigned to the commander's staff. In the past year, these analysts evaluated and documented the results of more than a dozen small-scale exercises. The analysts always aimed at reporting their findings while the events were still fresh in the minds of the participants. Almost always, their analyses were completed within a week of the encounter.

A major fleet exercise usually involves one or more full battle groups. Sometimes an exercise runs for several weeks; often it requires the services of a large team of analysts. CNA analysts contributed to the planning, reconstruction, and analysis of every major battle group exercise held in the past year. In the forward-deployed fleets, where there are relatively few analysts, the main source of exercise support has often been the local network of CNA field representatives, augmented as necessary by CNA-Washington. These analysts have played a major role in disseminating throughout the fleet the lessons learned during an exercise. Their findings have been documented in command reports, added to the curriculum of the Navy's Tactical Training Groups, and incorporated in the Navy's tactical publications. Although analysts at CNA-Washington have helped reconstruct and analyze individual exercises, their major contributions have been made

by distilling performance trends and tactical insights from the results of many different exercises. These are some of their efforts in 1982:

- A summary of battle group performance in antiair warfare and antisubmarine warfare, drawn from major fleet exercises between 1977 and 1980
- An analysis of how surface ships employed the Harpoon missile in six freeplay exercises
- An evaluation of the contribution of submarines to battle group defense in 75 exercises since 1970
- An assessment of the performance of tactical towed-array sonar in exercises and other operations, since 1976, when the system reached the fleet
- An evaluation of the accuracy of simulated torpedo attacks conducted during submarine-on-submarine exercises between 1977 and 1979.

Drawing on such work and on their own experience and analyses, teams of CNA researchers have helped the Fleet Commanders-in-Chief assess the ability of their forces to deal with Soviet forces, should the need arise. Three of these assessments were conducted in 1982; one looked at the Pacific Fleet, the others at U.S. Navy forces in the Mediterranean and Atlantic.

In the study of Pacific Fleet forces, the fleet commander's staff, the CNA representative with the staff, and analysts from CNA-Washington collaborated in work that ranged from the details of aircraft carrier operations to issues of naval strategy in the Pacific. The effort led to the first Pacific Fleet Capabilities Assessment, which:

- Established a computer data base of the numbers and kinds of ships, aircraft, weapons, and sensors in the U.S. and Soviet Pacific Fleets
- Evaluated the U.S. Pacific Fleet's ability to carry out selected offensive operations against the Soviets and to defend multiple-carrier battle groups

- Analyzed the Fleet's ability to sustain such operations, given its stocks of critical weapons (e.g., Phoenix and Harpoon missiles) and the numbers and types of ships available to supply combatants with food, fuel, weapons, and spare parts.

The Capabilities Assessment formed the basis of the 1982 Situation Report that the Commander-in-Chief, Pacific Fleet presented to the Joint Chiefs of Staff and the Senate Armed Services Subcommittee on Preparedness.

CNA's study of a 1982 Mediterranean campaign addressed concerns of the Commander in Chief, U.S. Naval Forces Europe (CinSUSNavEur), about the capability of his forces – and their ability to support operations ashore – when they are in the central and eastern Mediterranean, close to Soviet warships and within striking range of Soviet land-based aircraft.

The analysts calculated the likely outcomes of engagements that might follow an attack on the Sixth Fleet by Soviet naval forces, under a variety of circumstances. The study showed the effects of variations in U.S. force levels, and the contributions of NATO's land- and sea-based forces to attacks on land targets and defense against enemy air attacks.

In addition to helping CinCUSNavEur frame his concept of operations for the Mediterranean, the study identified some logistical difficulties that the Navy should correct in its effort to improve the effectiveness of the Sixth Fleet.

FUTURE FORCES AND SUPPORT SYSTEMS

Fire Support for Amphibious Operations

A year ago, CNA studied the ability of Navy and Marine Corps forces planned for the 1990s to successfully mount amphibious assaults. One portion of that study considered the availability of naval gunfire, strike aircraft, and other fire support systems to attack enemy positions on land, in preparation for an amphibious assault. The analysis indicated that the Navy might not have enough fire support for operations against some of our potential adversaries.

The Navy and Marine Corps then asked CNA to take a closer look at the adequacy of planned fire support forces, and to evaluate alternative ways of making up any deficiencies. This study was completed in 1982.

The first step in the analysis was to estimate the overall effectiveness of the fire support forces now planned for the 1990s – Naval warships, Navy and Marine Corps tactical aircraft, cruise missiles, and Marine Corps artillery – against potential enemy forces characterized as "low," "medium," and "high" threats. These forces and their likely disposition in the area of an amphibious assault were laid out in detail, to determine the targets that U.S. fire support forces might be called on to attack. The ability of enemy forces to attack the U.S. forces was also taken into account.

Many of the planned fire support forces can do more than lend fire support to amphibious operations. Aircraft carriers, for example, can attack naval bases and airfields as part of a larger campaign and can defend the sea lanes from enemy forces. The analysis therefore considered variations in the numbers of planned forces available to support an amphibious operation.

Despite some uncertainty about availability, planned forces seem adequate for operations against the "low" and "medium" threats. To deal with the "high" threat, however, it may be necessary to develop and procure new systems. The study evaluated the costs and effectiveness of several alternatives, from placing more naval guns on the ships the Navy expects to have to constructing a new type of ship with an advanced, medium-range missile system.

It is clear, however, that present plans for reactivating Iowa-class battleships, with their 16-inch guns, will add significantly to the fire support available to amphibious forces, at relatively low cost.

In a separate study, requested by the Navy, CNA considered how the battleships should be modernized after reactivation. The options analyzed included adding facilities for helicopters or for aircraft that can take off and land vertically or in short distances (V/STOL); outfitting the ships with cruise missiles, either to augment or to replace their naval guns; adding air defense systems, for either area defense or self-protection; and upgrading the ships' command, control, and communications suites.

The CNA study team incorporated various combinations of these options in six conceptual designs for modernized battleships, estimated the costs of modernization and operation for each design, and evaluated them for consistency with the likely missions for battleships. The Navy has drawn on these evaluations in making its decisions about modernization.

New Missiles for Fleet Air Defense

A primary mission of the U.S. Navy's cruisers and destroyers is protecting the battle group from air attack. Soviet Naval Aviation bombers armed with cruise missiles now pose a severe threat to these forces. The high speeds and small sizes of the missiles make them difficult to engage effectively; this difficulty will increase as the Soviets continue to improve their missiles.

To counter the Soviet's present missiles, the Navy is placing the Aegis weapon system on many of its new ships. This system consists of the Aegis radar (SPY-1A) and the latest in the Standard Missile family, the SM-2 Block II. The Navy is now considering the design of the next generation of missiles for the Aegis system.

The Navy chose CNA to lead a review team to evaluate the alternative missile designs for the decision makers who are concerned with this major investment issue. The study team evaluated the candidate missiles for their ability to shoot down advanced Soviet missiles within the detection range of the SPY-1A radar. The team also evaluated the technological risks associated with the candidates, their development schedules, costs, and potential for combat at longer ranges. The results of this investigation were presented to the Navy's leadership and to senior officials in the Office of the Secretary of Defense.

The Navy decided that the choice of a new missile should not be made without undertaking a comprehensive assessment of new systems and tactics for long-range aerial combat. CNA was asked to take a leading role in the assessment, which will be completed in 1983.

Logistic Support for ASW Helicopters

The Navy is beginning to deploy a new antisubmarine warfare (ASW) system called LAMPS Mark III. When an enemy submarine is detected,

a helicopter is sent out to find it and attack it. The helicopters are based on destroyers and frigates, which can operate with both Navy battle groups and convoys of merchant ships.

It is generally recognized that effective logistic support of LAMPS Mark III will be costly. There are several reasons for this: Helicopters will be deployed on ships in units of only one or two; the fewer aircraft in one location, the more parts must be stocked for each aircraft, against the chance that a part will be needed for one of them. Nor can the ships share spare parts easily, because they will not necessarily operate near each other. Finally, because there is little space for repair facilities aboard ship, more repair facilities must be built ashore or more spare parts bought in lieu of repair.

To help keep down the cost of LAMPS Mark III, the Navy asked CNA to examine logistic support options for the system and determine which could sustain the system's operations at the lowest cost. CNA examined 12 options, which differed in terms of the location of supply and maintenance facilities and the mix of one- and two-helicopter detachments.

To estimate the costs of the options, the CNA study team developed a model that determines the lowest cost package of spares, given a maintenance and supply network and a goal for the operational availability of the system. The model takes into account the geographic dispersion of ships, repair facilities, and supply points, and the structure of the repair and supply network. With this model, the study team found that the planned package of spares could be reconfigured to support the Navy's planned use of LAMPS helicopters, at a savings of nearly $200 million – with the planned repair and supply network.

If that network were allowed to vary, and some one-helicopter detachments were consolidated into two-helicopter detachments, additional savings are possible:

- Repairing all failed parts at central depots and eliminating intermediate repair facilities would save $80 million
- Using two-helicopter detachements whenever possible would save $95-198 million, depending on the configuration of the supply and maintenance network

- Using one ship in each task group as a central supply point for the task group would save $122-225 million, depending on the number of helicopters per detachment.

On the other hand, deploying two-helicopter detachments or relying on central supply ships in task groups would reduce the ability of LAMPS Mark III to respond to threats in different areas and to cope with unexpectedly high rates of part failure.

The study team also evaluated less-complex models the Navy could use regularly to determine the mix and level of parts to stock. The Navy is adopting the model recommended by CNA, at a saving of $70 million in spare parts for LAMPS Mk III.

How Much Automation of Marine Corps Command and Control?

CNA continues to assess for the Marine Corps its plans to improve battlefield command and control. In 1982, three CNA studies helped the Marine Corps to decide whether to adopt new, automated systems.

The Position Location and Reporting System (PLRS) helps ground combat units and tactical aircraft pinpoint their location, in relation to other Marine Corps units, enemy forces, and tactical objectives. PLRS also gives battlefield headquarters the same information, instantaneously, thus enhancing the ability of battlefield commanders to react to changing situations. An alternative, the Global Positioning System (GPS), was found to be only one-sixth as costly and somewhat more accurate. However, GPS lacks some of the capabilities of PLRS, in particular, the ability to instantaneously report the position of ground combat units and tactical aircraft to battlefield headquarters. Weighing these options, the Marines concluded that PLRS is worth the extra cost and decided to procure it.

The Marine Corps is considering the purchase of the Digital Communications Terminal (DCT), which transmits messages in rapid bursts, making them less susceptible to interception. It can also store incoming messages for later reference. CNA found that the device had not met reliability specifications and might not prove to be as useful as had been expected. The Marine Corps is reconsidering the number of DCTs it will buy and has deferred its long-term commitment until the reliability of the device is demonstrated.

The Tactical Combat Operations (TCO) system is intended to organize and display data obtained from intelligence sources and status reports. It is a computerized system that would replace the present system of situation assessment, which relies on index cards, acetate overlays on maps, and grease pencils. TCO's use of computers to store and recall data would enable battlefield commanders to receive a wider variety of reports and charts, and to receive them faster. CNA's analysis suggested that TCO would be worth the extra cost, if it could be designed to suit the specific information needs of the units that used it. The best way to arrive at a design for the system, therefore, is to let the design evolve through use, rather than locking it in ahead of time. The Marine Corps is considering this strategy for TCO and other automated systems for command and control.

A New Generation of Vehicles for the Marine Corps

The Marine Corps depends mainly on trucks and trailers to move troops, weapons, ammunition, and supplies around the battlefield. Today's fleet of Marine Corps trucks and trailers is old, inadequate, and ill-suited to new concepts of maneuver warfare. Before deciding what types and numbers of new vehicles to buy, the Marines asked CNA to reassess its needs and evaluate candidates for a new fleet.

The CNA study team first estimated the demands that would be placed on a vehicle fleet by a Marine Amphibious Force (MAF) – a division-wing team – during an amphibious assault and subsequent operations ashore. The estimates took into account the composition of combat units, the rate at which they are likely to consume ammunition and supplies, and their frequency of movement. Adding to these estimates the numbers of vehicles needed to replace those in repair, lost in combat, and needed for non-combat operations, the study team found that today's inventory of vehicles may be too small.

The analysts then considered which of three new fleets would meet the Marines' needs, at the lowest cost. They compared a fleet of vehicles much like today's with two fleets of newer, more mobile vehicles. Their comparison led them to recommend a fleet built around the Dragon Wagon (a power unit that can be combined with various types of powered trailers). The Marine Corps has approved the Dragon Wagon for service use and is now assessing its procurement plans for new vehicles.

MANPOWER AND MANAGEMENT

Strengthening the Navy's Enlisted Personnel Force

CNA's specialists in manpower believe that high priority should be assigned to the study of productivity, to relate the effectiveness and readiness of the armed forces to the skill mix and experience level of military personnel. With a better understanding of these relationships, the military services will be able to get more out of a given manpower budget, by changing the proportions of skills and experience in their forces.

CNA's past research in personnel productivity includes two major studies in the 1970s; they analyzed the effects of crew skills and seniority on ship performance. A study completed in 1982 reviewed the state of the art in the measurement of personnel productivity and tested a statistical approach.

The test project examined the relationship between skill level and seniority, on the one hand, and the mission-capable rates of carrier-based aircraft, on the other. Data for 180 deployments by Navy attack squadrons were analyzed. The analysis showed that men in higher paygrades (the measure of skill level) and longer experience (measured by years of Naval service) had much higher marginal productivities than their less-skilled juniors. Taking into account the costs of recruiting, training, and paying personnel enough to keep them in the Navy, the analysis showed that the mission-capable rates of attack aircraft could be raised substantially by increasing the number of top-grade enlisted men, while decreasing the number of lower-grade personnel.

Navy officials agreed that continuing this line of research could lead to a fundamental change in the Navy's manpower policies.

Even now, however, the Navy cannot attain its objective force of careerists, that is, personnel who have reenlisted at the end of their first term of service and are thus likely to stay in the Navy until retirement. As Naval forces expand through the 1980s, more careerists will be needed to man them.

The Navy can develop a larger career force either by increasing the accession of recruits, so that more people reach the point of making a career decision, or by reenlisting a larger fraction of those who do get to that point. The first strategy incurs higher recruiting and training costs. The second strategy requires larger expenditures on reenlistment bonuses. In 1982, CNA conducted a study to find a balance of accession and retention policies that would efficiently expand the career force.

A balance was determined for each of 28 occupational groupings of Navy personnel. Training costs for each of the occupational groups were estimated. The training costs were combined with recruiting costs – derived from earlier CNA research – to arrive at the cost of an additional accession to each grouping. CNA's model of the effects of bonuses on reenlistments was used to estimate the cost of increasing retention in each grouping.

The CNA team found that the Navy's enlisted career force objectives can be attained far more efficiently through measures to increase retention:

- Increasing the number of positions eligible for bonuses
- Removing the current cap on the bonus any individual may receive
- Continuing to allocate more bonuses to occupational groupings with high training costs.

For example, plans for Naval expansion call for an increase of 39 percent in the number of enlisted personnel in their fifth year of service. The annual cost of maintaining this larger force would be $200 million lower if current policies were modified, as suggested above. On the other hand, without reenlistment bonuses, the annual cost of meeting the Navy's career-force goals would rise by $2 billion.

Better Tools for Navy Decision-Makers

Efficient use of tax dollars for defense depends on more than efficiency in individual defense activities. The various elements of the defense program – development projects, procurement programs, force structures, manpower management policies, logistics networks, and

operating practices – must be consistent with each other and with defense strategy.

Since 1970, the primary vehicle for ensuring such consistency has been the Program Objectives Memorandum (POM). Every year, each of the military services submits to the Secretary of Defense its POM, which covers the coming budget year and the four following years. The POM details the service's plans for carrying out the Secretary of Defense's strategy guidance, within the funding limit that the Secretary places on that service's program; that limit is called "fiscal guidance."

In the early 1970s, CNA developed a cost model that enabled the Navy to evaluate alternative programs quickly and consistently, before settling on one for the POM. CNA's work also influenced the Navy's procedures for POM development.

In the years since, the procedures have changed from time to time, in response to specific directives from the Secretary of Defense and changes in the Navy's organization. These piecemeal changes have left Navy and Defense officials with the feeling that the Navy's procedures are cumbersome, unable to produce a flexible enough program.

In 1982, the Navy asked CNA to review the procedures and recommend changes. These recommendations indicate some of the major problems the CNA study team found, and how the problems could be solved:

- The documents that treat each of the Navy's warfare and support functions should address consistent, explicit force employment concepts and readiness goals, approved by the Chief of Naval Operations and announced at the outset of POM development.

- The documents should present tradeoffs within fiscal constraints, rather than identify so-called "requirements shortfalls." The tradeoffs should be expressed in terms of changes in the level of mission performance or readiness.

- New models are needed to help participants develop tradeoffs and estimate their effects on performance and readiness, quickly and consistently.

The Navy officials who received these findings agreed with them and have begun to implement them. Their efforts have been aided by two additional CNA projects.

In one project, CNA analysts developed the prototype of a decision document that presents tradeoffs within fiscal constraints and compares the alternatives in terms of mission performance. The mission chosen for the prototype was antiair warfare (AAW). The prototype showed how alternative AAW systems could be compared, even when uncertainty about their costs and effectiveness is significant and they vary with respect to useful lifetime.

In the second project, CNA analysts developed a model that is helping the Navy in its deliberations on the types and amounts of ordnance to include in its POM.

Every year the Navy spends more than $2 billion on "threat" ordnance – the torpedoes and missiles that would be fired at enemy submarines, surface ships, aircraft, and antiship missiles. Despite the size of these expenditures and the critical dependence of mission performance on ordnance, the Navy has lacked a clear and widely understood method for deciding how much to spend on threat ordnance and how to allocate the spending. The Navy has relied on a model that is mathematically complex, treats combat as though it all occurred instantaneously without enemy counterattacks, and yields a single estimate of how much ordnance is needed (an "inventory objective"); it does not relate spending on ordnance to the outcomes of combat.

The CNA analysts developed a simpler, more transparent method of determining the appropriate mix and level of threat ordnance inventories. The cornerstone of the method is a combat model that calculates the relationship between the size of an inventory and such measures of effectiveness as the number of enemy targets killed, the survivability of U.S. submarines and carrier battle groups, and the number of attack sorties that can be defended by fighter escorts. On the basis of these results and the cost of acquiring each inventory, the model determines the relationship between expenditures on ordnance and combat effectiveness. For a given expenditure, the effectiveness of various mixes of ordnance procurements can then be evaluated, quickly.

The calculations of effectiveness are based on simple formulas that are based on the probabilities of detecting and attacking enemy forces, the sizes of weapon salvos and probabilities of kill. The input values can be changed, as better ones emerge from tests, exercises, and more detailed analyses. The effects of time are captured by specifying the rates of encountering enemy forces and changes in the types of missions U.S. forces perform as the war goes on. The calculations also account for attacks by enemy forces on U.S. forces. The effects of resupply operations are treated by estimating the rate at which available resupply ships could deliver ordnance to the combat forces.

After designing the model, the study team worked with the Navy to develop an agreed set of input values, encounter rates, and missions. Since then, the CNA analysts have been helping the Navy set up and use the model in developing the POM that will go to the Secretary of Defense in 1983. After that, a computerized version of the model will be turned over to the Navy.

NON-DEFENSE RESEARCH

In 1970, the Secretary of Defense suggested that the talents and techniques that have been applied successfully to defense analysis by such organizations as CNA be applied to non-defense problems in the public sector, as well. CNA responded by establishing the Public Research Institute (PRI), which has worked on such subjects as the economic effects of imports on employment, the employment implications of technical progress, and the adequacy and economic effects of unemployment insurance systems. An example of such research – completed by PRI analysts in 1982 – was sponsored by the Labor Department's Bureau of International Labor Affairs, which administers programs to help workers who have been adversely affected by imports.

The Trade Expansion Act of 1962 reduced tariffs and quotas on goods imported into the United States. The act also established a new program, Trade Adjustment Assistance (TAA), to compensate U.S. workers who were hurt by the reductions. As it turned out, trade liberalization caused little damage, and compensation had seldom to be paid.

Under the Trade Act of 1974, TAA benefits were made available to workers laid off because of competition from imports, whether or not

the competition resulted from the lowering of barriers to trade. Implementing guidelines were not set until late 1975.

Although expansion of TAA carried the program far beyond its originally intended scope, it also provided evidence about two questions of interest to the Bureau of International Labor Affairs:

- Are workers in firms that suffer from competition with imports any worse off than workers in firms that face only domestic competitors?
- Does the fact that extra benefits are offered to some workers reduce their incentive to work?

To examine these issues, CNA analyzed the employment and earnings histories of a large sample of workers in Pennsylvania, including TAA beneficiaries, Unemployment Insurance recipients who were not eligible for TAA benefits, and workers who were not eligible for either kind of benefit. TAA recipients and carefully matched control groups of nonrecipients were compared with respect to unemployment and earnings.

First, to find out whether the TAA program selected for special compensation only those workers who had been hurt by imports, the CNA analysts compared the earnings of TAA recipients with the earnings of similar workers in the same industry who had been laid off and had collected UI benefits, but not TAA. (The comparison focused on workers who had been laid off in 1974 or early 1975, before the wider availability of benefits had become clear.) No important differences were found. Unemployment among TAA recipients and UI-only recipients, alike, was due mainly to temporary rather than permanent layoffs; they were unemployed for about the same length of time, and their post-layoff earnings were indistinguishable. In other words, the TAA program gave extra benefits to a group of workers whose unemployment problems were no worse than those of other workers.

Among workers laid off in 1976-77, however, TAA recipients stayed unemployed longer, and their earnings losses were greater (mostly due to the longer unemployment). This finding, which would otherwise have been surprising in view of the generally stronger performance of the economy in 1976-77, is attributable to the effects of TAA on incentives. Total benefits available to TAA recipients (tax-free and

equal to 70 percent of average weekly wages for 52 weeks in the two years following layoff) apparently encouraged workers to remain unemployed longer while waiting for recall.

RESEARCH AT THE UNIVERSITY OF ROCHESTER

The agreement between the Navy Department and the University of Rochester does not provide a management fee. Instead, five percent of CNA's budget is allocated to unclassified research at the University on subjects of long-term interest and potential value to the Navy. The subjects range over various disciplines, including the physical and engineering sciences, applied mathematics, medicine, and economics and other social sciences. The program for the 1981-82 academic year comprised 24 projects.

ORGANIZATION

The organization of CNA is depicted on page 32. The three operating groups – the Operations Evaluation Group, Naval Studies Group, and Marine Corps Operations Analysis Group – which conduct the Center's defense research, and the Public Research Institute, which conducts non-defense research, are supervised by the Office of the President. Administrative support and computing services are provided by the Office of the Vice President for Finance and Administration. The Board of Overseers regularly reviews the quality of CNA's research and management. (See section VI of this report for a description of the Board's responsibilities and membership.)

OFFICE OF THE PRESIDENT

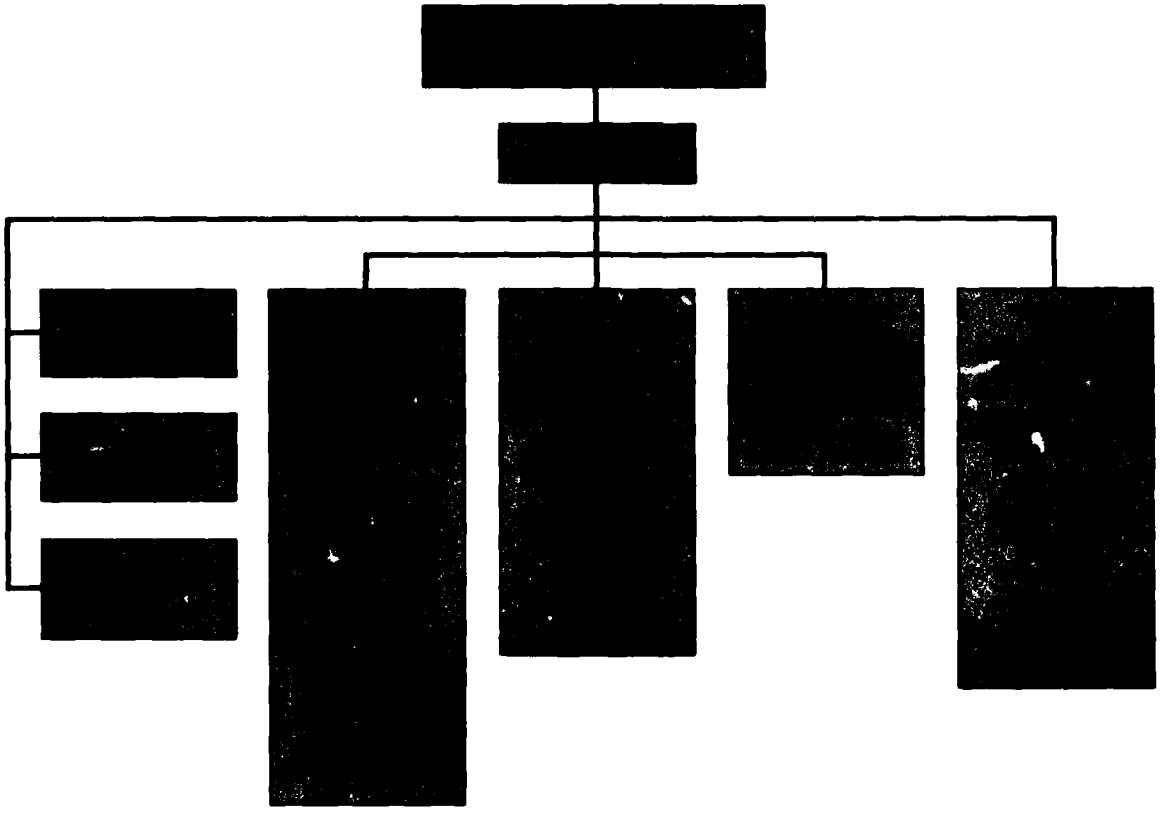
The *President* of CNA is responsible to the Board of Overseers and the University of Rochester for all of CNA's activities. He selects the management, organizes the Center's activities, sees to the quality and pertinence of its work, makes certain that it meets its contractual and security obligations, and sets its policies and budgets. He works with the Navy's Scientific Officer for CNA (the Director of Navy Program Planning) to determine CNA's research program. The President also attends to CNA's relations with the Department of the Navy, with the broader community of national security analysts, and with the analytical profession generally.

The *Director of Review* monitors the quality of CNA's research reports for the President. He follows CNA's studies and reviews a sample of the finished products to see that CNA's work meets the University's standards of analytical quality and that the results are so presented as to be clear and useful to decision-makers. Detailed reviews of CNA's research reports are normally conducted in the operating groups, according to guidelines set by the Director of Review.

The *Director for Naval Matters*, a senior Navy captain, is assigned to the Center by the Scientific Officer for CNA (Op-090), with the concurrence of the President of CNA. The DNM has administrative responsibility for the Operations Study Group (see below), and maintains liaison with the Bureau of Naval Personnel to keep the Operations Study Group staffed with qualified personnel. He also conducts special analyses within the CNA program, as directed by the President.

The Operations Study Group (OSG) comprises the 22 Naval officers and 3 enlisted personnel assigned to CNA as working members of the

THE ORGANIZATION OF CNA



analytical and support staffs. They are selected on the basis of military experience and performance, as well as academic background (16 of the officers hold advanced degrees). Another 7 full-time officers are authorized in the group, but because of Navy manning shortages these billets are vacant. In 1982, however, 13 officers were assigned for various periods of temporary duty to assist in CNA's research and gain analytical experience.

Though the members of OSG report to the Director of Naval Matters for administrative purposes, they work side by side with civilian professionals. While they are in OSG-CNA, their work is directed by the President of CNA.

Aside from the valuable analytical contributions of the members of OSG, they provide the rest of CNA's research staff with practical experience, technical knowledge, and a user's point of view. They are quick to point out any discrepancies between theoretical analyses and the realities of naval operations and warfare.

OPERATING GROUPS

The three operating groups – each headed by a Vice President of CNA – have their own fields of specialization.

Operations Evaluation Group (OEG)

OEG has the longest history of any of CNA's operating groups, dating back to 1942, when it was known as the Anti-Submarine Warfare Operations Research Group. At first, the group helped devise ways of combating the German U-boat attacks on U.S. shipping. The group's success in this endeavor led to a broadening of the types of naval warfare to which it applied quantitative analysis. A main result of these wartime contributions was the permanent establishment of OEG, with the support of Admiral of the Fleet Ernest J. King.

As discussed at length in section I, the field program, also born of World War II, remains an important part of OEG's activities. OEG's field representatives return from one- or two-year tours with the fleet, to be replaced by others from the Washington area office. There is thus a continuing infusion of practical experience into CNA's formal studies. This is matched by a counter-infusion of up-to-date knowledge of analytical techniques into OEG's program. CNA and the Navy have

long felt that this program leads to far more practical and realistic analyses than would be possible if the analysts never left their desks in Washington. OEG has a professional staff of more than 60, of whom 36 are assigned to Navy commands, as shown in the map and table on page 2, in section I.

The main emphasis in OEG remains what it was in the earliest days of the organization – getting the most out of the forces at hand and sending scientists to sea to help in that process. OEG is concerned with how best to use the Navy the nation has today and is committed to for the next few years. This is the concern not only of OEG's field representatives, but also of its Washington-based analysts, who both conduct their own research and augment the efforts of their colleagues in the field. Most of OEG's work falls into three categories: evaluation of system performance, tactical development and evaluation, and assessment of fleet effectiveness.

System performance is evaluated both before and after systems reach the fleet. An example of this work is the evaluation of the ability of available systems to jam bombing radars at long range, as discussed in section II of the report. Such operational testing often uncovers technical problems that can be corrected through minor design changes or improved maintenance procedures.

The combat effectiveness of Naval forces is more than a technical matter, however. For example, the effectiveness of jamming depends not only on technical performance of the jamming systems but also on the position of the systems, relative to the unit they are trying to "hide" from enemy bombers, and on the coordinated use of those systems. OEG thus devotes a large part of its effort to developing and evaluating tactics for individual weapon systems and forces equipped with a variety of weapon systems.

The third major type of activity – assessment of fleet effectiveness – helps planners and force commanders judge how well Naval missions can be carried out by current weapon systems, forces, and tactics. OEG's assessments are based largely on major fleet exercises, which OEG analysts help to plan, then reconstruct and analyze. Analyses of individual exercises point the way to specific improvements in training and operational procedures; summaries of many exercises help to form realistic estimates of Naval force effectiveness.

Naval Studies Group (NSG)

NSG is concerned with issues that face Navy planners and resource managers in Washington. To gain the most leverage from its research staff of 80, including 10 Naval officers, NSG places an emphasis on issues with broad policy and resource implications, and goes beyond standard applications of the methods of operations research, systems analysis, and econometrics. This outline of the activities of NSG's primary research programs indicates the scope of the group's concerns:

The program in *Naval Strategy* assesses the likely development of Soviet military doctrine and its implications for U.S. naval strategy and missions. This work is augmented by detailed analyses of Soviet naval forces, designed to determine their intended roles in combat. U.S. naval strategy options for the near term are constrained by the current Navy force structure, which can evolve but slowly, by the warfighting concepts underlying that force structure, and by the capabilities of allied naval forces. These constraints and their strategic implications have been a major subject of the program's research.

Naval Applications of Advanced Technology is aimed at helping Navy planners exploit the potential of such new technology as space sensors and weapons, improved undersea sensors, and advanced antiaircraft missiles. This program bridges the gap between basic research and force planning by estimating the contributions of new technology to the performance of the Navy's missions, and by assessing the technical risks involved in developing and producing systems that incorporate the new technology.

The Navy's choice of new weapon systems, of course, rests on more than the feasibility of producing such systems. The decision to procure, operate, man, and support a new system represents a commitment to spend funds that could be used to acquire other new systems or enhance the readiness of current forces. Moreover, the commitment to a new system carries implications for the missions that future Naval forces can carry out and the strategy options available to the National Command Authority. The program in *Long-Term Naval Force Planning,* therefore, examines these broader implications of new systems. A current project in this program considers the future role of long-range cruise missiles: What missions could they add to the Navy's repertoire? To what extent might they substitute for present types of Naval

forces? How would the substitution affect the Navy's ability to carry out missions for which cruise missiles are not suited?

The program in *Naval Warfare* looks in more detail at the factors influencing the course and outcome of future naval combat, not only force size and firepower – the usual preoccupations of warfare analyses in the past – but also the acquisition and denial of strategic and tactical information. The influence of these factors is examined in the context of vital Navy missions. A current project focuses on the Navy's ability to conduct wartime missions on the northern flank of NATO, including support of ground forces attempting to repel a Soviet invasion of Norway, and preventing Soviet naval and air forces from breaking into the North Atlantic.

Because the Navy's ability to carry out its missions depends critically on the availability of personnel and materiel, and how these resources are utilized to promote readiness, the program in *Manpower, Support, and Readiness* considers such issues. A challenging subject of current attention is the effect of complexity on the readiness of forces for combat. Continuing research in manpower is concerned with ways to meet the personnel needs of a larger Navy, in the face of a declining population of youths.

The sixth program, *Navy Management*, evaluates the mechanisms for translating analysis and other forms of information into programs and budgets and seeing to their execution. On the basis of these evaluations, analysts in this program recommend changes in decision-making procedures and develop management information tools. An example of such a tool is the model for evaluating alternative expenditures on ordnance inventories, described in section II of this report.

A seventh program, *Special Studies*, provides central management of a diverse set of relatively small projects that are funded apart from CNA's prime contract. The program gives the Navy additional access to the expertise developed in CNA's operations analysis and study programs. Projects range from studies of Soviet shipbuilding programs to assessments of proposed Navy weapon systems, and from engineering analyses of ship vulnerability to econometric forecasts of the Navy's enlisted personnel force.

In addition to its program of studies, NSG sponsors conferences. Their purpose is to bring together Navy officials, CNA analysts, and other

experts to discuss the policy implications of research and specific needs for future research. Three such conferences were held in FY 1982.

The first, organized by the Naval Warfare Program – and sponsored by the Director of Naval Warfare in the Office of the Chief of Naval Operations – was concerned with the protection of wartime shipping in the North Atlantic. At the conference, representatives of U.S. and NATO planning agencies, analytical groups, and operational commands discussed five main subjects: the probable threat to shipping, sealift needs and resources, concepts of operation, studies and analyses, and readiness. Special attention was given to Soviet intentions regarding the sea lanes, sealift resources available to the Allies, and the relative effectiveness of various measures to guard ocean shipping.

The second conference – on manpower research in the 1980s – was sponsored by the Manpower, Support, and Readiness Program. This conference drew on manpower experts from the military, government, and private sector, as well as CNA. Workshops ranged the field of manpower research: requirements, recruiting, training, retention, retirement, reserves and mobilization, civilian manpower, and policy integration. A consensus of the conference was the need for more research into personnel productivity.

The third conference took up the material readiness of U.S. forces and their capacity for sustained combat. This conference was sponsored by the Assistant Secretary of Defense for Manpower, Reserve Affairs, and Logistics, and organized by the Manpower, Support, and Readiness Program. The presentations by representatives of the military services and analytic organizations showed that substantial progress has been made in relating the expenditure on support resources – manpower and logistics – to the combat effectiveness of military forces. Nevertheless, much more attention should be given to the tradeoff between support resources and forces.

Further ideas for research came from the advisory councils that have been established for NSG's six primary programs. These councils, consisting of small groups of recognized experts from outside CNA, advise on the design and conduct of the study program. The councils include members of CNA's Board of Overseers, highly qualified former military leaders, civilian representatives of the research community,

and recognized experts from academia and industry. These advisory councils play an important role in linking CNA to sources of new ideas and new information.

Marine Corps Operations Analysis Group (MCOAG)

MCOAG's professional staff of more than 20 analyzes a wide range of problems for Marine Corps Headquarters in Washington and for three commands in the field: Fleet Marine Force, Atlantic, at Norfolk, Virginia; Fleet Marine Force, Pacific, at Honolulu, Hawaii; and Marine Aviation Weapons and Tactics Squadron at Yuma, Arizona. MCOAG research deals with current operations and future systems for amphibious assault, ground combat, tactical air warfare, and antiair warfare forces, as well as their manpower and logistics.

In operations, for example, MCOAG has been involved in joint Navy and Marine Corps tests to assess the ability of AV-8 Harriers and helicopters to operate from the same ship, at the same time. In 1982, MCOAG analysts helped to plan an initial, small-scale test. MCOAG will be involved in a larger test in 1983.

In 1981, MCOAG conducted a major force planning study called Assault-90. (See "Shaping Tomorrow's Amphibious Forces" in the 1981 Annual Report.) It evaluated options for modernizing amphibious lift forces and assessed the ability of the Navy and Marine Corps to carry out amphibious assaults, given planned lift and support forces. As a result of Assault-90, the Marine Corps has been re-examining its force structure, the size of its amphibious assault forces, and its amphibious warfare doctrine. MCOAG has been assisting in these endeavors.

An important example of MCOAG's work in manpower is its continuing analysis of the aptitude tests that are taken by prospective recruits of all the armed forces. This work has benefited not only the Marine Corps but the other services as well, because all four services use the same tests. The first important result of MCOAG's research in this area was to identify the incorrect "normalization," or calibration, of the tests that were in use several years ago. As a result, in 1980, the Department of Defense revealed that military recruits were less intelligent than had previously been reported; the raw scores on the tests were being converted into percentile scores that were too high. In

addition, MCOAG analysts have also normalized the tests currently in use. MCOAG has also evaluated the ability of these new tests to predict the performance of Marine recruits in their occupational schools. And MCOAG has identified the appropriate test scores for entrance into the various Marine Corps schools. Finally, MCOAG's specialists in manpower have developed several tools to identify recruiters and recruits who may be cheating on the aptitude tests. These tools are now used routinely by the Army and the Marine Corps.

OFFICE OF THE VICE PRESIDENT FOR FINANCE AND ADMINISTRATION

The Vice President for Finance and Administration is responsible for all matters relating to financial and contractual management, for programs affecting physical security, for compliance with the Industrial Security Regulations of the Defense Investigative Service, for publication and distribution of research reports, for personnel recruiting and management, and for CNA's computational facilities and services. These activities are organized into five departments:

Computing Services is responsible for operation of the computer center, for centralized programming, and for a proper match between the capabilities of computing resources and the needs of CNA users. The Computing Services staff provides computing, consulting, and programming support for both the CNA research program and the administrative departments.

Finance and Accounting provides cost and management accounting reports, financial management services, contract administration, and procurement services.

Information Services has two main functions in support of research: (1) acquisition, dissemination, and control of research materials, and (2) production and distribution of completed research reports. This department is also responsible for managing CNA's classified and unclassified libraries.

Personnel provides recruiting, interviewing, and testing services, maintains personnel records, administers the salary and fringe benefits program, and manages CNA's Equal Employment and Affirmative Action programs.

Security assures compliance with the Industrial Security Regulations of the Defense Investigative Service and is responsible for providing building maintenance and office service support.

In addition to these support activities, the Vice President for Finance and Administration is also responsible for a new *Information Systems Research Program*. To help the Navy cope with rapid advances in information technology, particularly computer-based systems and telecommunications, CNA recently established this research program. Projects will investigate information requirements, conceptual design of systems, testing and evaluation of systems, and operational implementation. Initial research is concerned with computer-based information systems to handle tactical information for the operating forces of the Navy.

PERSONNEL

One of CNA's foremost management goals is the recruitment, retention, and development of a first-rate research staff. CNA's management devotes considerable time each year toward achieving this goal. This section briefly profiles the research staff and outlines some of CNA's personnel management policies.

RECRUITING

CNA's college recruiting program focuses on the most prestigious institutions in the nation. Recruiting at conventions supplements the college program to bring CNA in contact with both new and experienced talent from a variety of academic disciplines. These activities are augmented by search programs designed to attract senior professionals with impressive credentials in the field of defense analysis. This table shows the source of hires for CNA's professional staff in the past five years.

PROFESSIONAL RECRUITING
1978 – 1982

Source of hires	Percent
University (student)	35
Private industry	20
University (faculty or staff)	23
Non-profit organization	6
Federal government	13
Military	3
Total	100

STAFF COMPOSITION

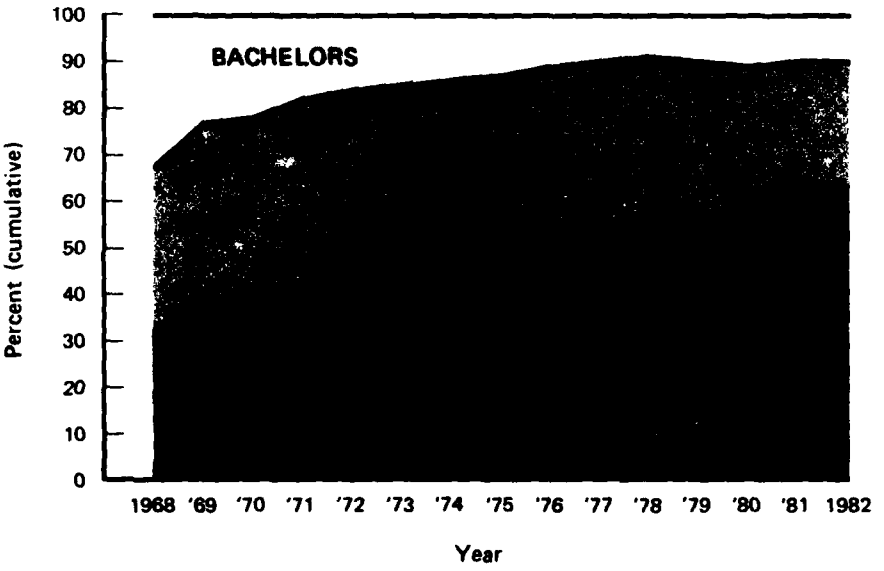
During 1981, CNA reexamined carefully the organization and management of its research activities. An important outcome of this review was the establishment, in 1982, of a new staff classification: Research Program Director (RPD). RPDs are senior analysts who give specialized direction and leadership to CNA's diverse research interests. They are

able to do this by leading relatively small teams, usually of no more than 12 professional staff members. And, because they have few administrative responsibilities, RPDs are able to keep abreast of issues that may warrant analysis by CNA, while closely monitoring – and participating in – their research programs.

Since the University of Rochester assumed management responsibility for CNA, 15 years ago, special attention has been directed at building the credentials of CNA's professional staff. Progress in this regard is reflected by the change in the proportion of the staff holding graduate degrees:

RESEARCH STAFF DEGREE LEVELS

(1968-1982)



The high percentage of staff members holding advanced degrees gives CNA an important advantage in conducting research of critical importance to the nation's defense. The table below compares the educational credentials of CNA's staff with those of similar research organizations.

POSTGRADUATE DEGREES
(Proportion of professional staff, 1982)*

	Doctor's	Master's	Total
Center for Naval Analyses	63%	27%	90%
16 contract research centers	29	33	62
32 Federal research laboratories	17	20	37
48 profit-seeking firms	16	27	43

CNA al· ·akes pride in the practical experience of its staff and the influence of their operations analyses for the fleets on CNA studies of planning issues for Navy offices in Washington. Almost half of CNA's research staff has spent one or more tours in field assignments at Navy and Marine Corps commands, where they have acquired first-hand knowledge of the forces, systems, and operations they are called upon to analyze at CNA-Washington. Researchers with field experience have spent, on average, 3.4 years in the field.

More generally, the research staff's professional work experience averages 13.5 years, with 9.3 years of that in defense research. The staff's experience, combined with postgraduate education that averages 4.5 years, sets CNA apart from most organizations in the credentials that its staff brings to bear on significant national defense issues.

The diverse nature of CNA's research program requires a mix of academic disciplines. These are the disciplines represented in the research staff:

	Number	Percentage of staff
Physics and chemistry	48	28
Economics, business, and finance	36	21
Mathematics and statistics	35	21
Engineering	20	12
Operations research	11	6
Psychology and sociology	5	3
History	4	2
Political science and international relations	3	2
Other	9	5
Total	171	100

** Source: "National Survey of Compensation Paid Scientists and Engineers Engaged in Research and Development Activities," Battelle Memorial Institute, Columbus, Ohio, November 1982.*

SALARIES

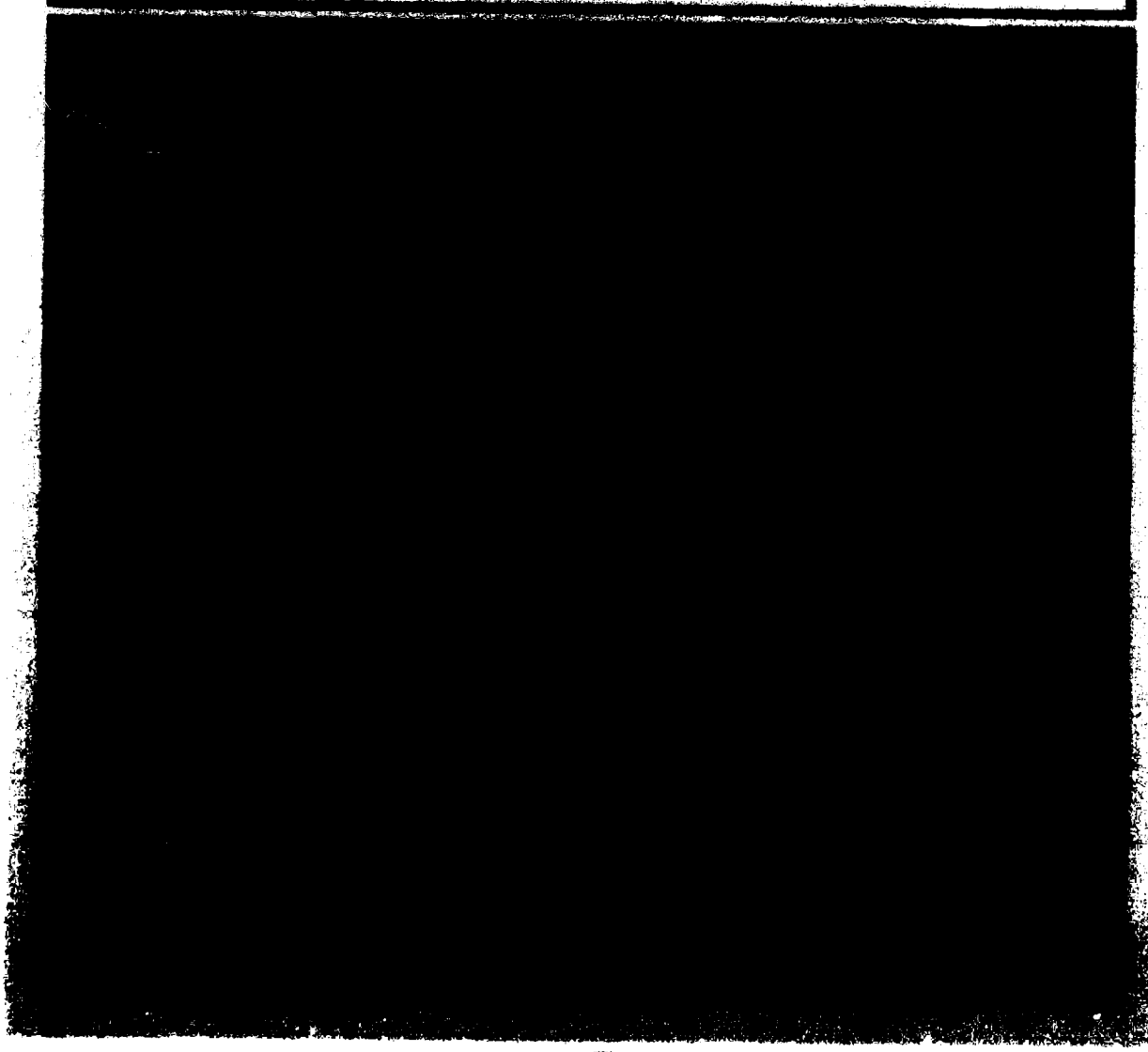
The Vice Presidents approve all offers of employment and all actions affecting research staff salaries. Any salary above the basic pay authorized for Level IV of the Senior Executive Schedule must also be approved by the CNA Board of Overseers and by the Navy's Contracting Officer.

To make sure that CNA salaries are competitive, CNA's management analyzes salary survey data drawn from a large national sample of scientists and engineers by degree, specialty, and level of experience. This information is supplemented by informal exchanges with organizations conducting research similar to CNA's. Individual salaries and research accomplishments are reviewed every year.

EQUAL OPPORTUNITY

CNA has long supported the principle of equal opportunity, regardless of race, creed, color, national origin, sex, age, or physical handicap. To that end, CNA has established policies and practices in conformity with federal legislation. The main purposes of CNA's Affirmative Action Program are: (1) to make sure that, within each sector of the labor market drawn on by CNA, minorities and women are represented on the CNA staff to the same degree as they are in the sector as a whole, and (2) to provide all employees with opportunities for training and advancement. CNA continues to be dedicated to these objectives.

FINANCIAL INFORMATION



The Center for Naval Analyses is not a corporate entity; it operates as an affiliate of the University of Rochester. All contracts, bank accounts, and other legal agreements are carried in the University's name and are executed by designated officials of the University. Within this framework, CNA maintains an autonomous financial system for payroll, tax reporting, purchasing, cash management, and all standard accounting functions.

Funding

All of CNA's funding is provided through cost-reimbursable contracts and grants arranged with agencies of the federal government. Of the funding received during FY 1982, contracts with the Department of the Navy accounted for 98 percent. In lieu of a management fee, five percent of the funding awarded to CNA is allocated to the University of Rochester for unclassified research devoted to areas of potential interest to the Navy.

Property and Equipment

CNA owns no physical assets. Under the terms of CNA's contract, all property and equipment is either leased or purchased for the account of the federal government. As a result of this contract provision, and in the absence of a contract fee, CNA has no net worth or retained earnings.

Cash Requirements

Because CNA lacks other sources of capital, the organization's contracts call for the Navy to provide working capital through an advance funding account. Advances are drawn weekly on the basis of anticipated expenditures and offset by monthly vouchers.

Financial Controls

Financial control of CNA's operation is achieved through a system of budgeting and expense monitoring. At the start of the fiscal year, an operating budget is developed for each division within CNA. The division must then perform its assigned tasks within that budget. Monthly expenditures are closely monitored, and budgets are revised whenever there is a significant change in CNA's funding.

All contract expenditures are reviewed by the staff of the Vice President for Finance and Administration, to ensure compliance with federal regulations and contract provisions. Expenditures for travel, supplies, equipment, and consultants are documented by requisitions and approved by CNA's management. Major purchases must be approved in advance by the Navy's Administrative Contracting Officer. CNA's financial system is also audited regularly by the Defense Contract Audit Agency and the University's public accountant (Peat, Marwick, and Mitchell).

FUNDING IN FY 1982
(Thousands of Dollars)

Source of Funds	
Defense:	
CNO/CMC Study Program	$13,816
Tactical Development and Evaluation	2,914
Other programs	1,224
Total defense	$17,954
Non-defense:	
Department of Labor	$ 484
National Science Foundation	167
Total non-defense	$ 651
Total FY 1982 funds available	$18,605
Funds carried forward from FY 1981	660
Total funds expended	$19,265
Application of Funds	
CNA program costs	$18,350
On-campus research	915
Total funds applied	$19,265

STATEMENT OF COMPARATIVE FINANCIAL CONDITION
30 September 1982 and 30 September 1981

ASSETS

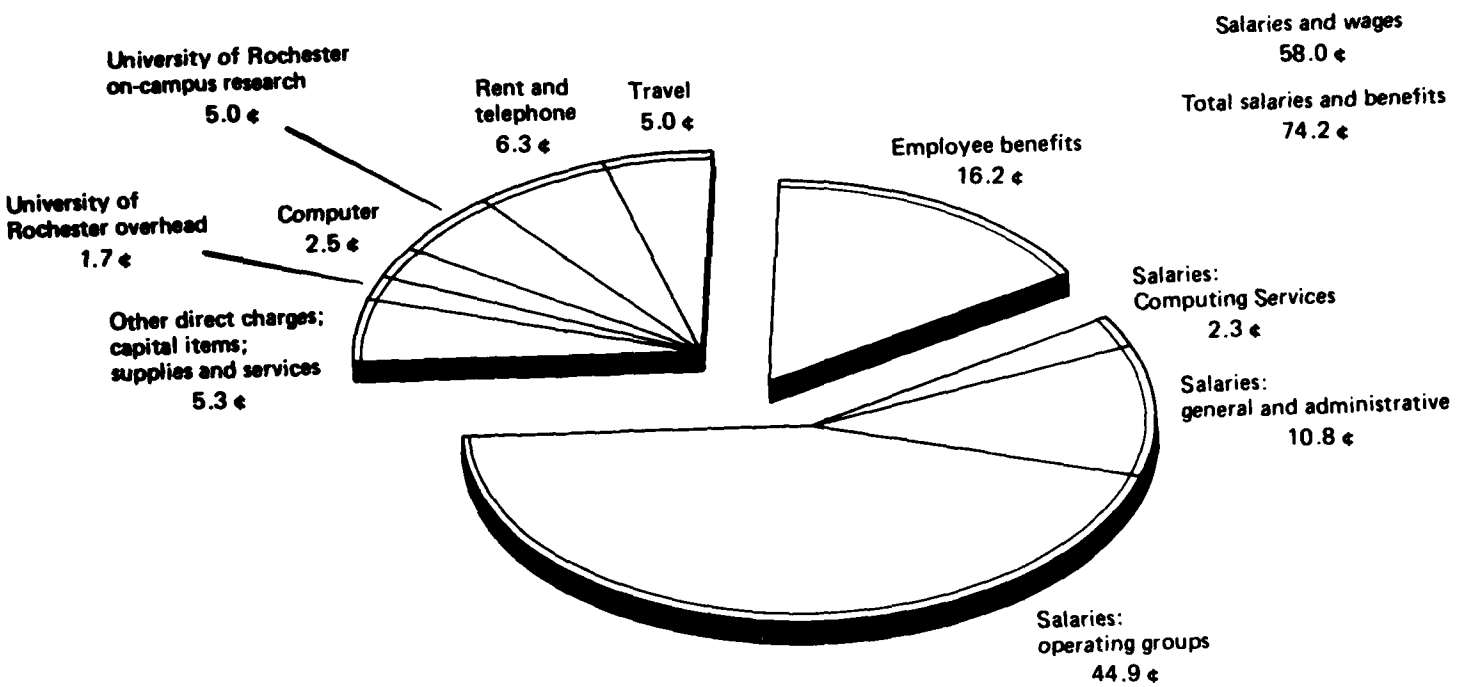
	1982	1981
Current assets		
Cash	$ 43,636	$ 191,336
Receivable (note 1)	109,491	143,958
Travel advances and prepaid items	437,882	580,254
Advances – U.S. Navy	644,733	241,859
Total current assets (note 2)	$1,235,742	$1,157,407

LIABILITIES AND RESERVE FOR DISALLOWANCES

Current liabilities		
Accounts payable	$ 215,120	$ 197,534
Payroll taxes and other withholdings	165,653	145,092
Total current liabilities	$ 380,773	$ 342,626
Other liabilities		
Accrued annual leave	$ 801,064	$ 772,643
Unbilled labor adjustments	53,905	42,138
Total other liabilities	$ 854,969	$ 814,781
Total liabilities	$1,235,742	$1,157,407

NOTES:
1. Government agencies account for over 95 percent of all receivables.
2. CNA has no physical assets. Property and equipment constitute direct charges, with title vesting in the government.

APPLICATION OF THE RESEARCH DOLLAR IN FY 1982



BOARD OF OVERSEERS

The Board of Overseers of the Center for Naval Analyses is responsible for formulating overall policy for CNA, maintaining high standards of professional competence and integrity in CNA's work, and reviewing the general managment policies and personnel of the organization.

At three meetings a year, the Board reviews the work of CNA. Most of these meetings are held at the Center's Washington area office, where the methods and results of four to six major research projects are presented in detail. Other meetings are held near CNA field locations, giving the Board an opportunity to review analyses done for the operating forces of the Navy and Marine Corps.

Sometimes, unclassified research for Navy, Marine Corps, and non-defense sponsors is discussed with the Board at a meeting held at the University. The Board also reviews some of the basic research that is conducted on campus, under the University's contract for management of CNA.

MEMBERS

Robert L. Sproull, Chairman
President and Chief Executive Officer of the University of Rochester

Martin J. Bailey, Professor of Economics, University of Maryland. Former Assistant for Southeast Asia Forces, Department of Defense.*

Andrew P. Borden, Vice President for the Naval Studies Group of the Center for Naval Analyses. Former Chief Scientist, Systems Analysis Division, Office of the Chief of Naval Operations.

Kenneth E. Clark, Professor of Psychology and former Dean of the College of Arts and Sciences, University of Rochester. Former member of the Army Science Board. Former consultant to the Office of Science and Technology.

Donald K. Hess, Vice President for Campus Affairs, University of Rochester. Former Director, U.S. Peace Corps. Former Director of Program Management, Advanced Research Projects Agency.

Arthur Kantrowitz, Professor of Engineering and Senior Lecturer in Engineering Sciences, Dartmouth College. Former Chairman and Chief Executive Officer of Avco Everett Research Laboratory. Honorary Trustee of the University of Rochester.

David Kassing, President of the Center for Naval Analyses.

William H. Meckling, Dean of the Graduate School of Management, University of Rochester. Former member of the National Science Board. Former Executive Director of the President's Commission on an All-Volunteer Armed Force. Former President of the Center for Naval Analyses.

Elliott W. Montroll, Professor, Institute for Physical Science and Technology, University of Maryland. Former Vice President, Institute for Defense Analyses.

William A. Nierenberg, Director of the Scripps Institution of Oceanography. Member, NASA Advisory Council. Member, National Academy of Sciences. Member, Defense Science Board, Member, panel on future military systems, Office of Science and Technology Policy. Chairman, JASON.

David S. Potter, Vice President and Group Executive in charge of the Public Affairs Group of General Motors. Former Under Secretary of the Navy. Member of the National Academy of Engineering.

Frank P. Sanders, Vice President of the Signal Companies, Inc. (Retired). Former Under Secretary of the Navy.

Brian J. Thompson, Dean of the College of Engineering and Applied Science, University of Rochester. Former Director of the Institute of Optics, University of Rochester.

LaRoy B. Thompson, Senior Vice President and Treasurer of the University of Rochester. Honorary Member (and former Chairman) of the Board of Associated Universities, Incorporated.

Adm. W.F.A. Wendt, USN (Ret.), former Deputy Chief of Naval Operations. Former Commander in Chief, U.S. Naval Forces, Europe.

Albert Wohlstetter, Senior Fellow of the Hoover Institution, Stanford University. Former member of the professional staff and Research Council, the Rand Corporation.

PAST MEMBERS

Carl Amthor (1969-72)
Charles J. DiBona (1967-73)
C. Donald Griffin (1968-82)
McCrea Hazlett (1967-71)
Hubert Heffner (1973-75)**
Robert Loewy (1967-74)
Stephen Lukasik (1975-77)
David A. McBride (1967-78)
Russell Murray 2nd (1974-77)
Patrick Parker (1967-72)
W. Allen Wallis (1967-82)
Clarence L.A. Wynd (1968-81)

*On leave of absence from the Board.
**Deceased.